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(54) **Separation of solids and water from crude oil**

(57) Crude oil containing produced solids and produced water is treated to remove a substantial proportion of the solids therefrom and then passed through a coalescer to produce a water phase and an oil phase. The coalescer can comprise a fibre such as paper or glass fibre but not a plate type or electrostatic separator.

The process can be used to treat a crude oil 2 to produce a purified portion 13 which can be used to lubricate the seals 12 of the pump 4 by removing solids (sand, salts, pipe scale etc) in a cyclone 8 and treating the solids-free oil 10,15 in the coalescers 18 and 22.

FIG.2

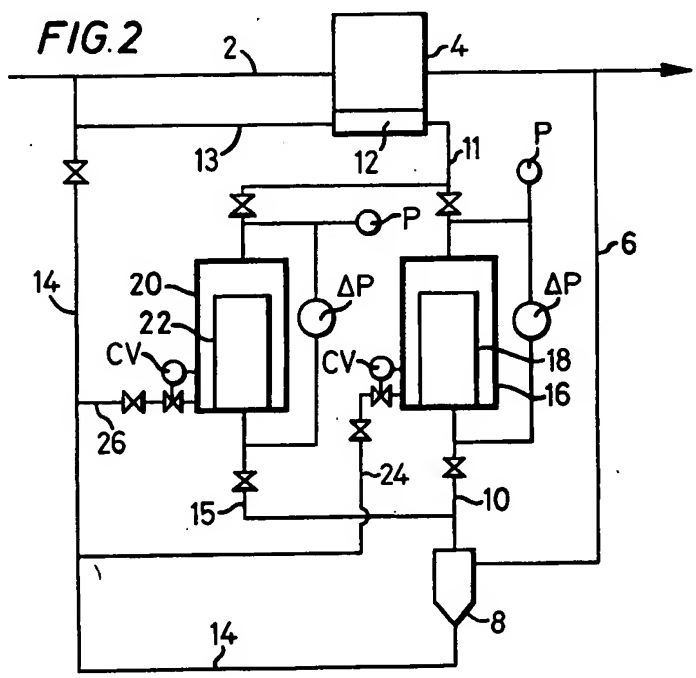

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FIG.1

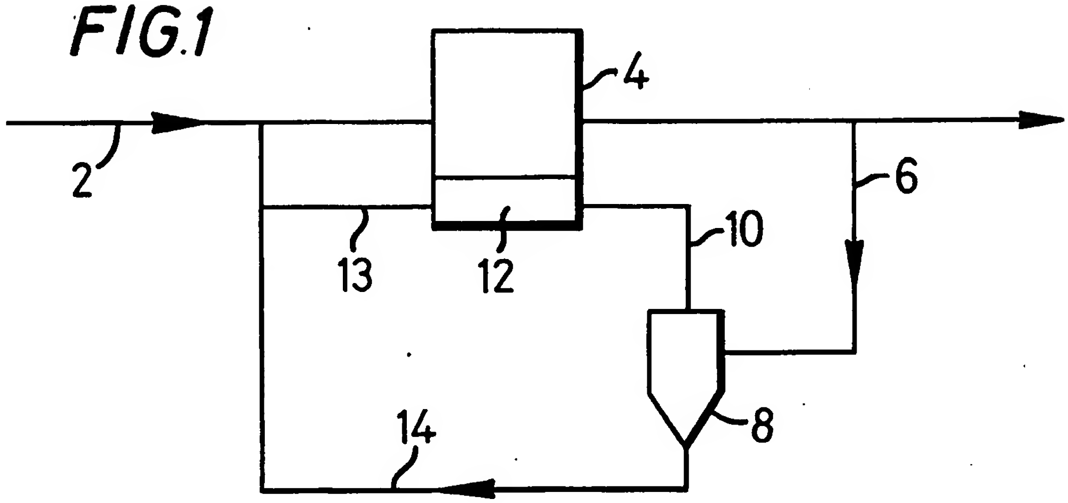
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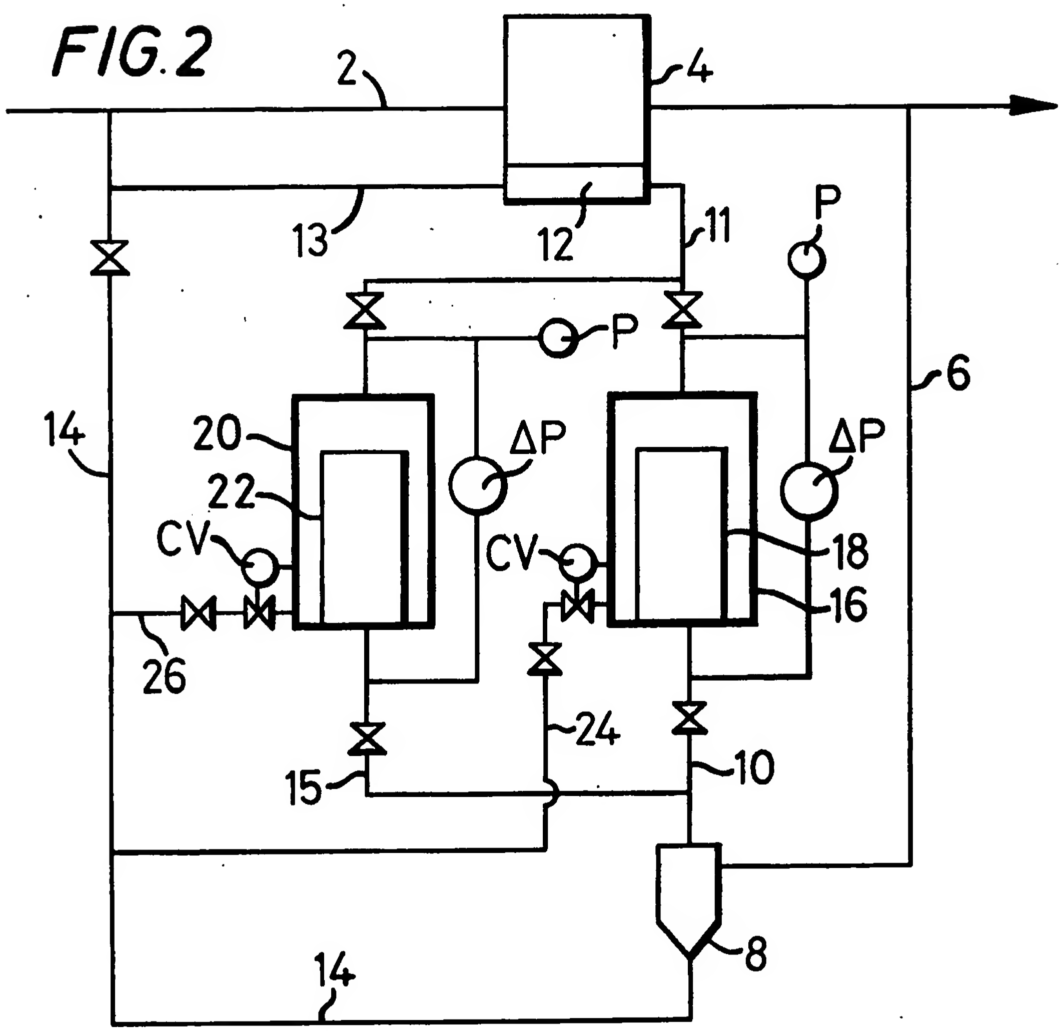
FIG.2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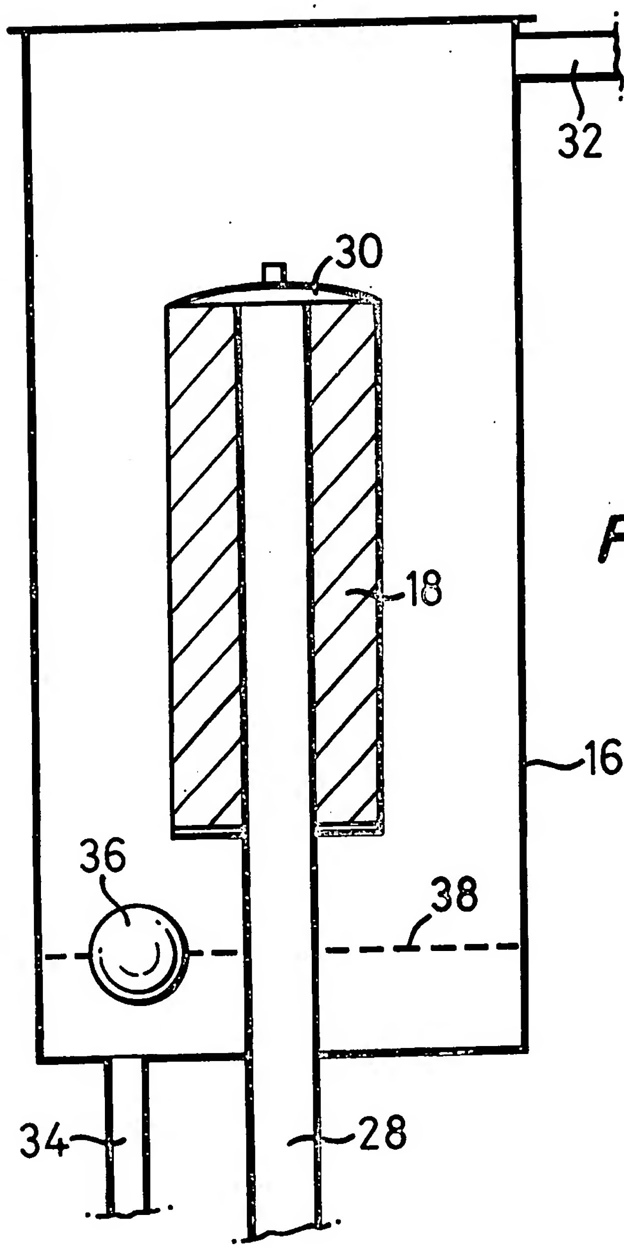

FIG.3

SPECIFICATION

Separation method and apparatus

This invention relates to a method of treating a crude oil containing produced solids and produced water and also to an apparatus therefor.

In the production of crude oil from an oilfield it is usual for the oil initially produced to be substantially water-free. However, during the life of the oilfield the proportion of water produced wtih the crude oil usually increases and a point is reached when it may be desirable to separate the oil from the produced water before transporting the oil from the wellhead either by pipeline or tanker.

Further, a portion of the crude oil may be employed to lubricate equipment and machinery forming part of the production facilities and for this purpose the presence of significant amounts of water is undesirable.

For the separation of certain oil and water mixtures it has been previously been proposed to employ a separator known as a coalescer. For example, coalescers have been previously proposed for removing minor amounts of water from aviation kerosene and from marine fuel oil and also for removing minor amounts of oil from aqueous effluents.

It is an object of the present invention to provide a method and apparatus for separating a feed mixture containing crude oil and produced water and produced solids to obtain an oil from which the water and solids has been substantially removed. The feed mixture will usually also contain gas in solution.

According to the present invention a method of treating a crude oil containing produced solids and produced water to produce an oil stream from which the solids and water have been substantially removed comprises passing the crude oil through a coalescer to produce a water phase and an oil phase and separating the two phases to form an oil stream from which the water has been substantially removed and a water stream.

The method can comprise pretreating the crude oil, for example, by passing through a cyclone or filter to remove a substantial proportion of the solids that would block the coalescer to yield an oil enriched in solids herein referred to as the solids stream and an oil from which the solids have been removed.

The method can conveniently be effected by either

(i) controlling the conditions at which the coalescer is operated so that the water content of the oil stream is less than 0.1% by weight, or

(ii) allowing the water content of the oil stream to exceed 0.1% by weight and passing the oil stream through another coalescer to reduce the water content below 0.1% by weight.

The amount of produced solids in the crude oil passed to the cyclone may be up to 1000 ppm and will usually be in the range 5 to 1000 ppm. The oil from the cyclone may contain less than 5 ppm preferably less than 1 ppm.

The water stream (to which may be added the solids stream from the cyclone mentioned above) can be returned to the untreated oil.

The oil treated by the method can be a crude oil, particularly a crude oil containing gas maintained in solution under pressure, the amount of which will depend on the pressure. It is convenient to have a substantial quantity of gas in solution since this reduces the viscosity of the mixture and facilitates separation. Suitable operating pressures for the cyclone are in the range such as to retain the dissolved gas in solution.

The purpose of the cyclone is to remove produced solids that are normally present in crude oils such as particles of sand, precipitated salts or pipe scale. These solids would rapidly block the coalescer and lead to a pressure build up and/or their presence in the oil would render it unsuitable for use as a lubricant, for example, in pump bearings.

The cyclone is operated in such a manner as to remove a substantial proportion of such solids and thus give the coalescer a reasonable working life, for example, when the pore size of the element in the coalescer is about 50 micron the cyclone will be operated to remove a substantial proportion of solids that would block pores of that size.

Preferably the method is effected at a temperature such that wax, if present, is maintained in solution to prevent blockage of the coalescer element.

The term coalescer is understood by those skilled in the art and refers to any means by which relatively small droplets of water or oil occurring in dispersions such as emulsions which do not readily separate under gravity are coalesced to facilitate separation.

For the avoidance of doubt, the term coalescer does not include plate type separators which are unable to separate the small droplets found in crude oil/water mixtures, and electrostatic separators.

Any coalescer element may comprise, for example, pleated paper, glass fibre or other fibrous material conveniently in the form of an annulus through which the mixture flows radially.

The pore size of the element will be chosen so that it is fine enough to effect coalescence but not so fine as to become rapidly blocked by solids in the oil from the cyclone. Usually the pore size of the element will be in the range 20 to 100 micron.

By pore size is meant that the element will retain 95% of particles of the specified pore size. Thus a 20 micron pore size element will retain 95% of particles of 20 micron.

The operation of the coalescer can be effected as follows: residence time of oil phase 0.1 to 5 mins.

preferably 0.5 to 3 mins.

Preferably the operation of the coalescer is effected so that the major component of the mixture (usually the oil) is the continuous phase on the downstream side of the coalescer element. The effect of this is that the coalesced water drops on leaving the coalescer element pass into the oil phase and settle under gravity towards the base of the coalescer vessel.

The coalescer element may be replaced in the event of a high pressure drop developing, for example, caused by trapped solids.

According to a preferred embodiment of the invention a method of treating a crude oil containing from 1 to 50% by weight of produced water, a minor amount of solids up to 1000 ppm to produce an oil containing less than 0.1% by weight of water comprises:

(a) passing the mixture through a cyclone to remove solids therefrom, and

(b) passing the oil from which solids have been removed containing gas in solution in amount sufficient to reduce the viscosity through a coalescer operated at superatmospheric pressure to retain the dissolved gas in solution and further so that coalesced droplets of water pass into a continuous oil phase on the downstream side of the coalescer and settle under gravity to produce an oil phase and a water phase and separating the two phases to form an oil stream and a water stream and either

(i) controlling the conditions at which the coalescer is operated so that the water content of the oil stream is less than 0.1% by weight, or

(ii) allowing the water content of the oil stream to exceed 0.1% by weight and passing the oil stream through another coalescer to reduce the water content below 0.1% by weight.

When the treated oil is used as a lubricant and/or coolant on equipment it may convenient to continuously cycle the treated oil in a closed system. For example, when used to lubricate pump seals, the treated oil that does not escape past the pump seals can be recycled and its volume made up as necessary.

According to another aspect of the present invention an apparatus for the treatment of a crude oil containing produced water and a minor amount of produced solids to produce an oil stream from which the solids have been substantially removed and containing not more than 1% by weight of water comprises:

(a) a cyclone for the removal of said produced solids,

(b) a vessel containing a coalescer element for the separation of the oil from which the produced solids have been removed into an oil stream and a water stream said coalescer element being connected to the vortex finder of the cyclone so that oil from which the solids have been removed is passed as feed to the coalescer vessel.

The pore size of the coalescer element can be in the range 30 to 70 microns.

The apparatus can include a second coalescer element located in a vessel for the separation of the oil from which the solids have been removed, said second coalescer vessel being connected to the vortex finder of the cyclone and to the first mentioned coalescer vessel to permit operation in series or in parallel with said first mentioned coalescer.

The second coalescer can be connected to the first coalescer vessel so that the oil stream is passed as feed thereto, said second coalescer having a pore size of 25 to 50 microns.

The invention is described by reference to the accompanying drawings in which

Figure 1 is a flow diagram of a previously used system for the removal of solids from crude oil withdrawn from a pipeline by means of a cyclone and the oil passed to the seals of a pump.

Figure 2 is a flow diagram of the system according to the present invention in which a pair of cartridge coalescers adapted for operation in parallel are interposed between the cyclone and the pumps seals.

Figure 3 is a vertical section showing the general arrangement of cartridge coalescer and the vessel in which it is located.

Referring to Figure 1 crude oil in line 2 is passed to main oil line pump 4 which emits the oil at a pressure of 2000 psig. From a point on the downstream side of pump 4 oil is withdrawn into line 6 at a rate of about 2 gallons/minute, the temperature of the oil being about 70°C, and passed as feed to a cyclone 8 to effect removal of solids. Oil from which solids have been removed is recovered as an overflow through the vortex finder of cyclone 8 and passed via line 10 to the seals 12 of pump 4 from where it passes via line 13. Solids are removed together with some oil as an underflow from cyclone 8 and passed via line 14 to join the oil in line 13 and blend with the oil in line 2 on the upstream side of pump 4.

Referring to Figure 2 oil which may contain up to 20% by wt of water is withdrawn from the downstream side of pump 4 and passed via line 6 to cyclone 8 as described above. Oil from which solids have been removed is passed by line 10 to a vessel 16 containing a cartridge coalescer 18 of annular form through which the oil is caused to flow radially outwardly. Oil enriched in solids (solids stream) is withdrawn from the base of cyclone 8 via line 14 and passed back to crude oil line 2. The content of the solids stream is not critical and thus the cyclone can be operated so as to optimise the quality of the oil fed to the coalescer. In a typical case about 30% by volume of the crude oil fed to the cyclone is passed to the coalescer. The coalesced water is separated by gravity on the downsteam side of the coalescer and the dewatered oil containing not more than 0.05% wt of water pased via line 11 to the seals 12. Water is withdrawn from coalescer vessel 16 via line 24 and passed to line 14 where it is blended wtih the solids containing stream and passed back to a point on the upstream side of pump 4. A second vessel 20 containing its coalescer 22 is arranged for operation in parallel or as a standby. Oil from which solids have been removed by cyclone 8 can be passed via line 15 to the vessel 20. Water is withdrawn via line 26 and passed to line 14 where it is blended with the solids

containing stream and passed back to a point in the upstream side of pump 4. Oil from which the water has been removed is passed via line 17 to line 11 and thence to pump seals 12. The coalescer is operated so that the continuous phase on the downstream side of the element is oil. Droplets of coalesced water therefore pass into the oil phase and settle under gravity towards the base of the vessel. The oil/water interface is controlled below the level of the coalescer element.

Referring to Figure 3 a vessel 16 has a cartridge coalescer element 18 located therein. The coalescer element 18 is of annular form and is disposed with its axis coaxial with the axis of the vessel 16. The coalescer element is made of glass fibres or pleated paper and has a pore size as herein defined of 30 micron. An inlet pipe 28 leads to the interior of the annular coalescer element 18 and has a closed end 30, so that incoming feed is caused to flow radially outwardly through the coalescer element 18.

The vessel has an upper outlet 32 for oil and a lower outlet 34 for water. A float 36 is provided for controlling the level of the oil/water interface.

Using the system described in Figures 2 and 3 a typical example was as follows:

Solids Removal

Feed to cyclone:

crude oil containing	10 ppm by wt of solids *	)
	10% wt water	) product A

the temperature of the feed was about 70°C and the residence time was about 0.5 minutes.

*The solids comprised particles of sand, precipitated salts, pipe scale and other material.

Product from cyclone:

crude oil containing	1 ppm by wt of solids	)
	10% wt water	) product B
solids stream		

Coalescer

Feed to coalescer:

as product B

the temperature of the feed was unchanged at about 70°C and the residence time of oil phase in coalescer vessel, 1 minute.

Products from Coalescer

Oil stream:

crude oil containing	1 ppm by wt of solids
	0.1% wt water

Water stream:

water containing	100 ppm of oil

CLAIMS

1. A method of treating a crude oil containing produced solids and produced water to produce an oil stream from which the solids and water have been substantially removed which method comprises treating the crude oil to remove a substantial proportion of the solids therefrom and passing the crude oil through a coalescer to produce a water phase and an oil phase and separating the two phases to form a water stream and the oil stream from which the water and solids have been substantially removed.

2. A method of treating a crude oil as claimed in claim 1 wherein the pretreating of the crude oil comprises passing through a cyclone to remove a substantial proportion of the solids that would block the coalescer, to yield an oil enriched in solids herein referred to as the solids stream and an oil from which the solids have been substantially removed.

3. A method of treating a crude oil as claimd in claim 1 or claim 2 wherein the method is effected by either

(i) controlling the conditions at which the coalescer is operated so that the water content of the oil stream is less than 0.1% by weight, or

(ii) allowing the water content of the oil stream to exceed 0.1% by weight and passing the oil stream through another coalescer to reduce the water content below 0.1% by weight.

4. A method of treating a crude oil as claimed in any one of claims 1 to 3 wherein the crude oil contains from 1 to 50% by weight of water, produced solids in amount from 5 to 1000 ppm and the treatment is effected at superatmospheric pressure to maintain dissolved gas in solution and the treated oil contains less than 5 ppm.

5. A method of treating a crude oil as claimed in any one of the preceding claims wherein the water

stream from the coalescer and the solids stream from the cyclone are passed to the untreated crude oil.

6. A method of treating a crude oil to obtain an oil suitable for use as a lubricant and/or coolant for equipment which method comprises removing produced solids and water from the crude oil by a method as claimed in any one of claims 1 to 5 and passing the oil to the equipment to be lubricanted and/or cooled.

7. A method of lubricating and/or cooling equipment which method comprises employing as lubricant and/or coolant a crude oil treated by a method as claimed in any one of Claims 1 to 6.

8. An apparatus for the treatment of a crude oil containing produced water and a minor amount of produced solids to produce an oil stream from which the solids have been substantially removed and containing not more than 0.1% by weight of water said apparatus comprising:
(a) a means for the removal of said produced solids,
(b) a vessel containing a coalescer element for the separation of the oil from which the solids have been removed into an oil stream and a water stream said coalescer vessel being connected to the vortex finder of the cyclone so that oil from which the solids have been removed is passed as feed to the coalescer vessel.

9. A method for the treatment of a crude oil substantially as hereinbefore described with reference to the Example.

10. An apparatus for the treatment of a crude oil substantially as hereinbefore described with reference to either Figure 2 or 3 of the accompanying drawings.

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

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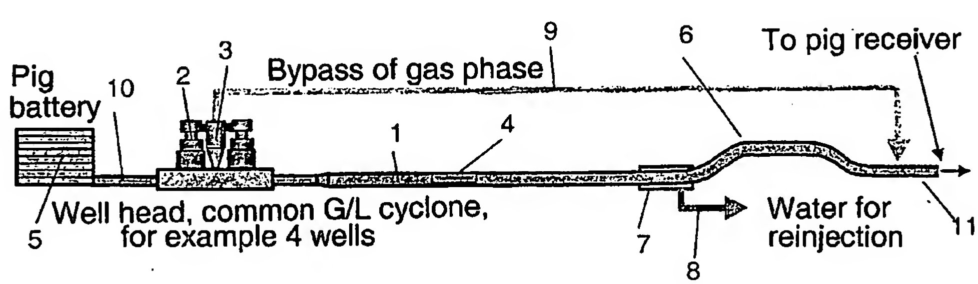
Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A PIPE SEPARATOR WITH IMPROVED SEPARATION



(57) Abstract: A pipe separator for separation of fluids, for example separation of oil, gas and water in connection with the extraction and production of oil and gas from formations under the sea bed. It comprises an extended, tubular separator body (1) that has a diameter at the inlet and outlet ends that is mainly equal to or slightly greater than the diameter of the transport pipe to which the separator body is connected. A cyclone (3) is arranged upstream of the separator body for separation of any gas present. An electrostatic coalescer (4) is incorporated in and constitutes an integrated part of the separator body (1).

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A Pipe Separator with Improved Separation

The present invention concerns a pipe separator for separation of fluids, for example separation of oil, gas and water in connection with the extraction and production of oil and gas from formations under the sea bed, comprising an extended, tubular separator body that has a diameter at the inlet and outlet ends that is mainly equivalent to the diameter of the transport pipe to which the pipe separator is connected, a cyclone arranged upstream of the separator body for separation of any gas present and an electrostatic coalescer arranged in connection with the pipe separator.

The applicant's own Norwegian patent application nos. 19994244, 20015048, 20016216, 20020619 and 20023919 describe prior art pipe separators for the separation of oil, water and/or gas downhole, on the sea bed or on the surface, on a platform or similar. In particular, patent application no. 20023919 shows a solution in which a separate, compact electrostatic coalescer is used in connection with the pipe separator. The oil flow from the pipe separator is passed to the coalescer downstream of the pipe separator and subsequently to a further oil/water separator that removes the remaining water after separation in the pipe separator. This prior art solution is particularly designed for, but not limited to, medium heavy oils with water removal from the oil phase to 0.5% water, using a cyclone or other type of gas/liquid separator to remove gas before the pipe separator.

The solution requires an additional separator, which is complicated and expensive, and the coalescer itself, which is of a vertical type, cannot be reamed or pigged (cleaned) in the conventional manner. This also represents a considerable disadvantage of the prior art solution.

The present invention represents a considerably simplified separation solution in which the above disadvantages are avoided. The present invention is characterised in that the electrostatic coalescer is incorporated in and constitutes an integrated part of the separator body, as stated in the attached claim 1.

The dependent claims 2-5 indicate the advantageous features of the present invention.

The present invention will be described in further detail in the following with reference to the attached drawings, where:

Fig. 1 shows an elementary sketch of a pipe separator in accordance with the present invention.

Fig. 2 shows an enlarged part of the separator shown in Fig. 1 in the area of the coalescer in a cross-section a) and a longitudinal section b).

The solution shown in Fig. 1 comprises a tubular separator body 1, a liquid seal 6, arranged downstream of the separator body, for the water phase in the fluid (oil/water) that flows through the separator, a drainage device 7 with an outlet 8 for the separated water, a pig battery 5, arranged upstream of the separator body in connection with a well head 9, a connection pipe 10 that connects the well head to the separator body 1 and a transport pipe 11 for oil downstream of the separator body. The special feature of the present invention is that a coalescer 4 is incorporated in the separator body 1 as an integrated unit. The coalescer is expediently arranged at a distance of between 1/3 and 1/2 of the length of the separator body from the inlet of the separator body. However, its location is not limited to this. Fig. 2 shows in large scale, in cross-section and longitudinal section, the part of the separator body in which the coalescer is incorporated. As the figure

shows, the coalescer comprises an upper electrode 12 and a lower electrode 13 that are enclosed in expediently insulating material in the wall 14 of the separator body. The electrodes are designed to have applied to them (not shown in further detail) an expedient voltage "V" (AC voltage) to create an electric field that contributes to increasing the separation of water from the fluid (oil and water) flowing through the separator. As Fig. 1 shows, a cyclone 3 (or another expedient gas/liquid separator) is arranged upstream of the separator body 1 to remove any gas from the fluid that is produced in the wells 9. The intention of removing the gas is to avoid it reducing the effect of the coalescer as the gas is a poor electrical conductor. Another intention is to prevent the formation of plug flow in the separator.

The method of operation of the separator solution in accordance with the present invention is otherwise as follows:

Fluid, i.e. gas, oil and water, that is produced is passed first to the cyclone 3, where the majority of gas is removed and passed on in a separate pipe 9, possibly being reintroduced into the transport pipe 11 after the separator.

The liquid phase, which may contain small amounts of gas, is introduced into the separator body 1. Free water will separate quickly and form a water phase under the oil phase. The gas bubbles will collect in the top of the separator pipe and, depending on their concentration, form a free gas phase. When coarse separation has been completed (i.e. the water phase on the bottom, the oil phase with small oil drops in the centre and possibly a thin gas phase on the top), the fluid will pass into the integrated coalescer 4.

In the coalescer 4, a voltage drop will be created mainly over the oil zone because the water zone conducts current and the gas zone also has good conduction properties.

The voltage drop over the oil zone (alternating current) produces increased drop coalescence and destabilises the oil/water interface. The water drops grow in size and will separate quickly after the fluid has entered the pipe separator element 1 again.

In the separator element downstream of the coalescer, the coalesced water drops will be separated out and collected in the collection unit 7, where the water is drained out via the pipe 8. The oil will flow on past the water seal 6 to the transport pipe 11.

The present invention as it is defined in the claims is not limited to the example shown and described above. The separator may be provided with two or more coalescers 4 arranged in series in the separator element 1. This may be particularly relevant for oils that are difficult to separate such as heavier oils.

The cyclone 3 may also be located in places other than the well head as shown in Fig. 1. It has proved expedient for the cyclone to be located in connection with equipment that causes high shear for the fluid as this produces good separation conditions. However, it may also be relevant to locate the cyclone in close proximity to the separator's inlet in situations in which the separator is located far from the well head.

Claims

1. A pipe separator for separation of fluids, for example separation of oil, gas and water in connection with the extraction and production of oil and gas from formations under the sea bed, comprising an extended, tubular separator body (1) that has a diameter at the inlet and outlet ends that is mainly equal to or slightly greater than the diameter of the transport pipe to which the separator body is connected, a separator device, expediently a cyclone (3), arranged upstream of the separator body for separation of any gas present and an electrostatic coalescer (4) arranged in connection with the pipe separator,
characterised in that
the electrostatic coalescer (4) is incorporated in and constitutes an integrated part of the separator body.

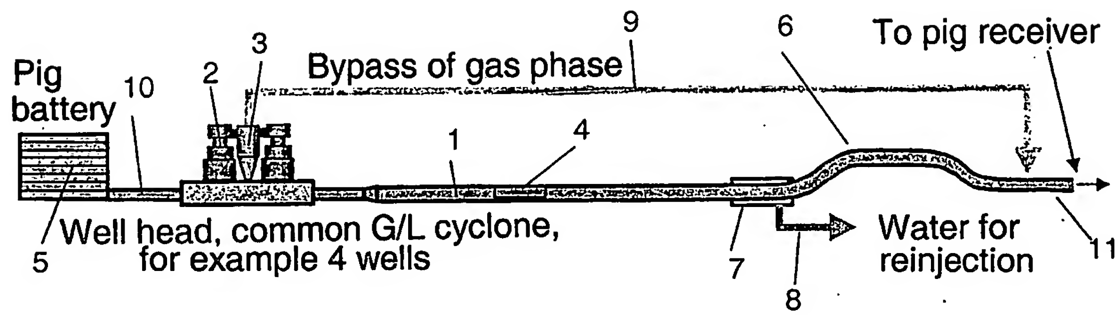
2. A pipe separator in accordance with claim 1,
characterised in that
a water seal (6) is arranged downstream of the separator element (1) and a device (7) is arranged in connection with the water seal for drainage of the water that is separated out in the separator element (1).

3. A pipe separator in accordance with claims 1 and 2,
characterised in that
the separator element (1) comprises two or more coalescers arranged in series.

4. A pipe separator in accordance with claims 1-2,
characterised in that
the cyclone (3) is arranged in connection with a throttle valve that produces high shear for the fluid.

5. A pipe separator in accordance with claims 1-2,
characterised in that
the cyclone (3) is arranged in close proximity to the inlet of the separator element (1).

Fig. 1


Pig
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3
Bypass of gas phase
9
6
To pig receiver
1
4
Well head, common G/L cyclone,
for example 4 wells
5
7
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Water for
reinjection
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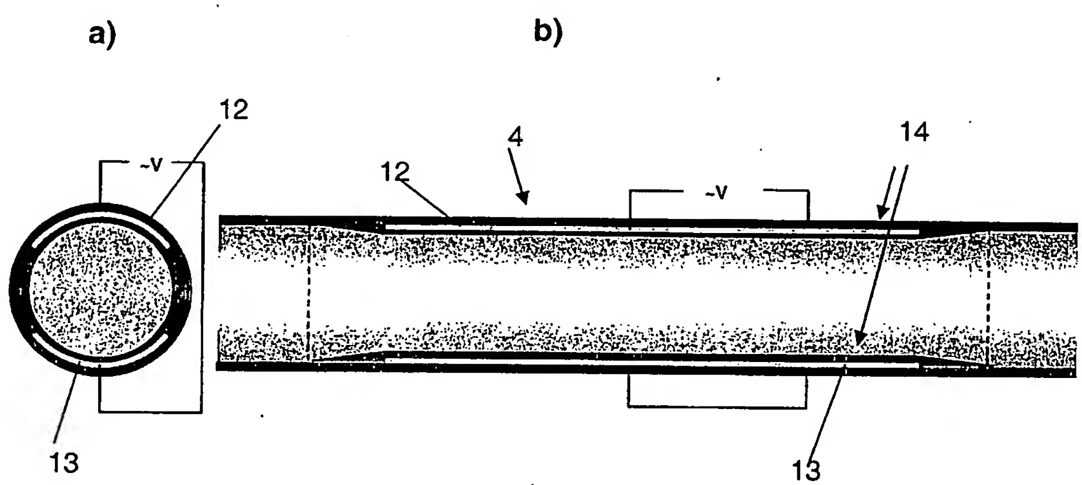
Fig. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 2004/000211

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: E21B 43/36, B01D 17/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: E21B, B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 0185297 A1 (ABB RESEARCH LTD.), 15 November 2001 (15.11.2001), page 2; page 6 - page 9, figures 1-4 --	1-5
A	WO 02089947 A1 (ABB RESEARCH LTD.), 14 November 2002 (14.11.2002) --	1-5
A	US 3766050 A (I. PADOS), 16 October 1973 (16.10.1973) -- --------	1-5

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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